Operative Techniques in
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Nonsternotomy Approaches to Left Ventricular Assist Device Placement: Combined Left Subcostal–Right Minithoracotomy Technique

Anelechi C Anyanwu, MD, FRCS

Alternative non-sternotomy approaches to implanting left ventricular assist devices have become viable and reproducible alternatives to standard sternotomy approach. This paper outlines the essential steps of the left subcostal- right-minithoracotomy approach for left ventricular assist device implantation. The left subcostal approach offers excellent access to the cardiac apex without disrupting the left chest wall, while the aorta can be easily accessed via a right mini-thoracotomy incision.
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KEYWORDS Left Ventricular Assist Device, Less Invasive Surgery, Sternotomy, Subcostal Incision

The standard method of implantation of an implantable left ventricular assist device (LVAD) involves a median sternotomy. We have adopted a nonsternotomy approach for implantation of the HeartMate II LVAD (Thoratec Inc, Pleasanton, CA) using a subcostal incision and a right minithoracotomy.[1] We use this technique for routine implantation of the HeartMate II LVAD in patients who have not had prior sternotomy and who do not need concurrent valve surgery. This technique is adaptable to other implantable LVADs but is described here for HeartMate II implantation (Figs. 1-12).

Patient Selection

This technique is unsuitable for patients with fibrous pericardial adhesions. Patients who would predictably have adhesions are therefore excluded from this approach, particularly those who have undergone prior cardiac surgery or pericardiotomy. Because of the need to place a side clamp on the ascending aorta, we routinely perform computed tomography scanning, and patients with moderate or severe aortic calcification are excluded from this approach. This technique may be used in patients in cardiogenic shock; however, unstable patients who require quick institution of bypass are probably best served with median sternotomy. Prior laparotomy or thoracotomy is not a contraindication to this approach. We have used this approach in patients with advanced lung disease, as we believe a right minithoracotomy is less disruptive on respiratory mechanics when compared with a sternotomy. A prior right thoracotomy in a patient with parenchymal lung disease is a contraindication. Patients who would predictably require a right ventricular assist device and patients requiring valvular heart surgery should undergo median sternotomy. A patent foramen ovale is not a contraindication as these can be closed via the right minithoracotomy or postoperatively using a percutaneous approach, if necessary.

Department of Cardiovascular Surgery, Mount Sinai Medical Center, New York, NY

Address reprint requests to Anelechi C. Anyanwu, MD, Department of Cardiothoracic Surgery, Mount Sinai Medical Center, 1190 5th Ave, New York, NY 10029. E-mail: anelechi.anyanwu@mountsinai.org, Vivian.Baez@mountsinai.org

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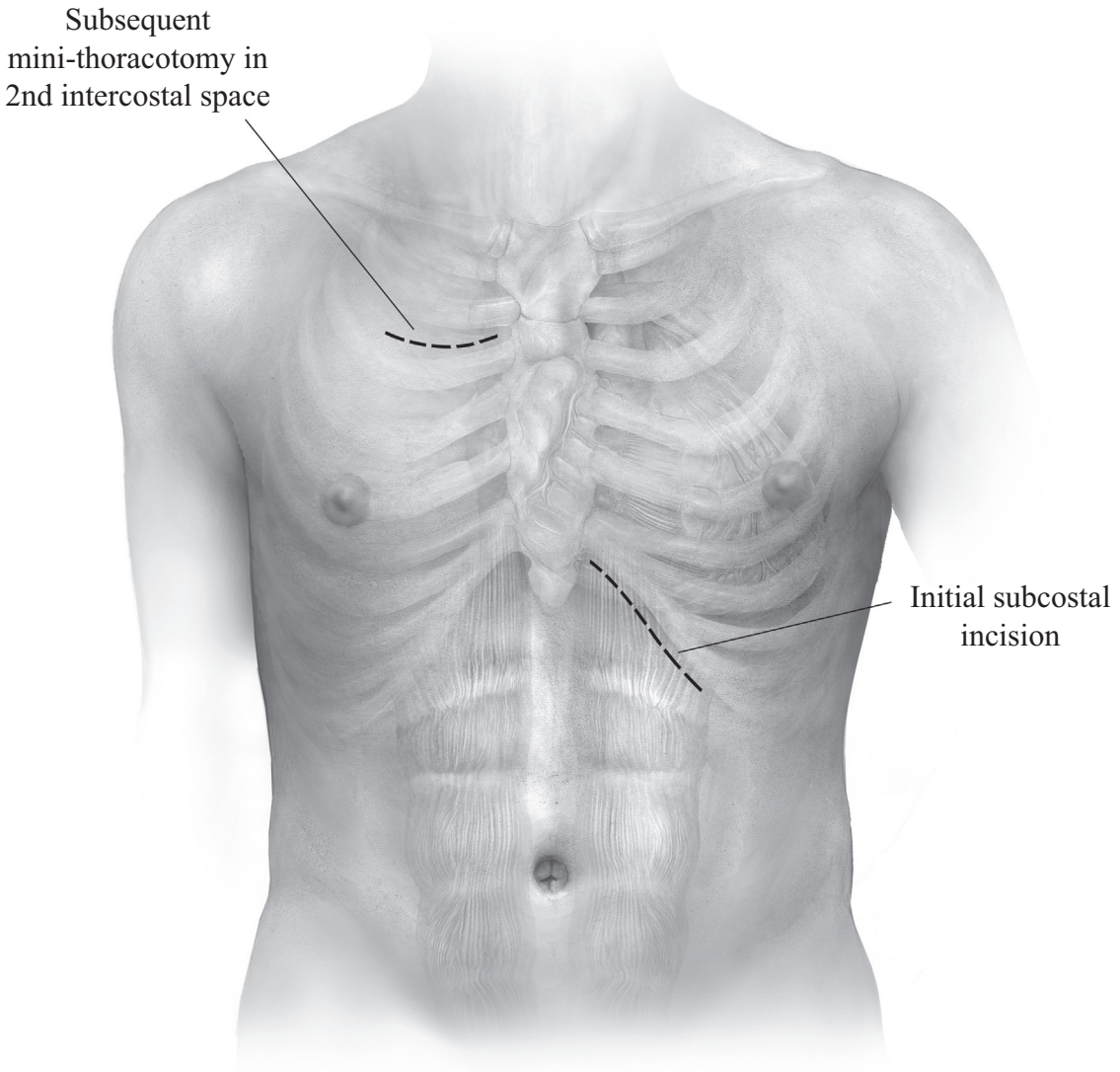

Figure 1 Anesthetic and surgical preparation is same as for implantation of HeartMate II through sternotomy. General anesthesia with a single lumen endotracheal tube is used. A transesophageal echocardiogram is performed to confirm that there are no valve dysfunctions or structural lesions that need surgical correction (if there are structural or valve lesions that need correction, then this technique is contraindicated, and the device should be implanted via median sternotomy to allow cardiac repair). External defibrillator paddles are placed. If the patient has an internal defibrillator, this is left active, as it may be used as a defibrillator later in the operation. A sterile magnet is placed over the device after draping to prevent interference by diathermy. The patient is placed in a supine position and prepared and draped as for a median sternotomy. A typically 8-12 cm long left subcostal incision is made, starting approximately 2 cm lateral to the xiphoid process and then extended laterally. The incision is deepened through the subcutaneous layers with cautery.

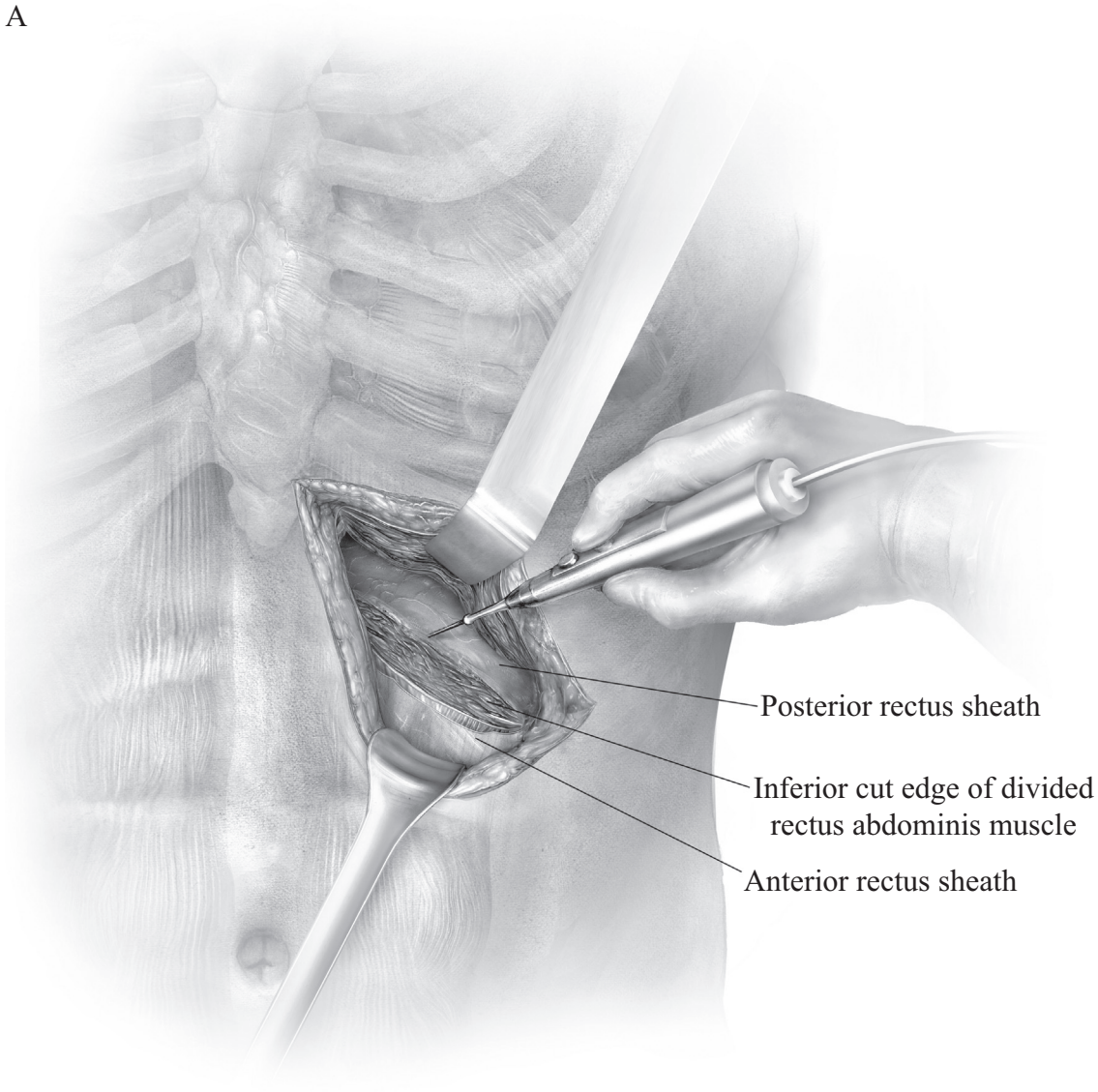

Figure 2 (A) The anterior rectus sheath and rectus muscle are incised in the line of the incision, but the integrity of the posterior rectus sheath is preserved. A pocket for the ventricular assist device is created anterior to the posterior rectus sheath by slightly undermining the edges.

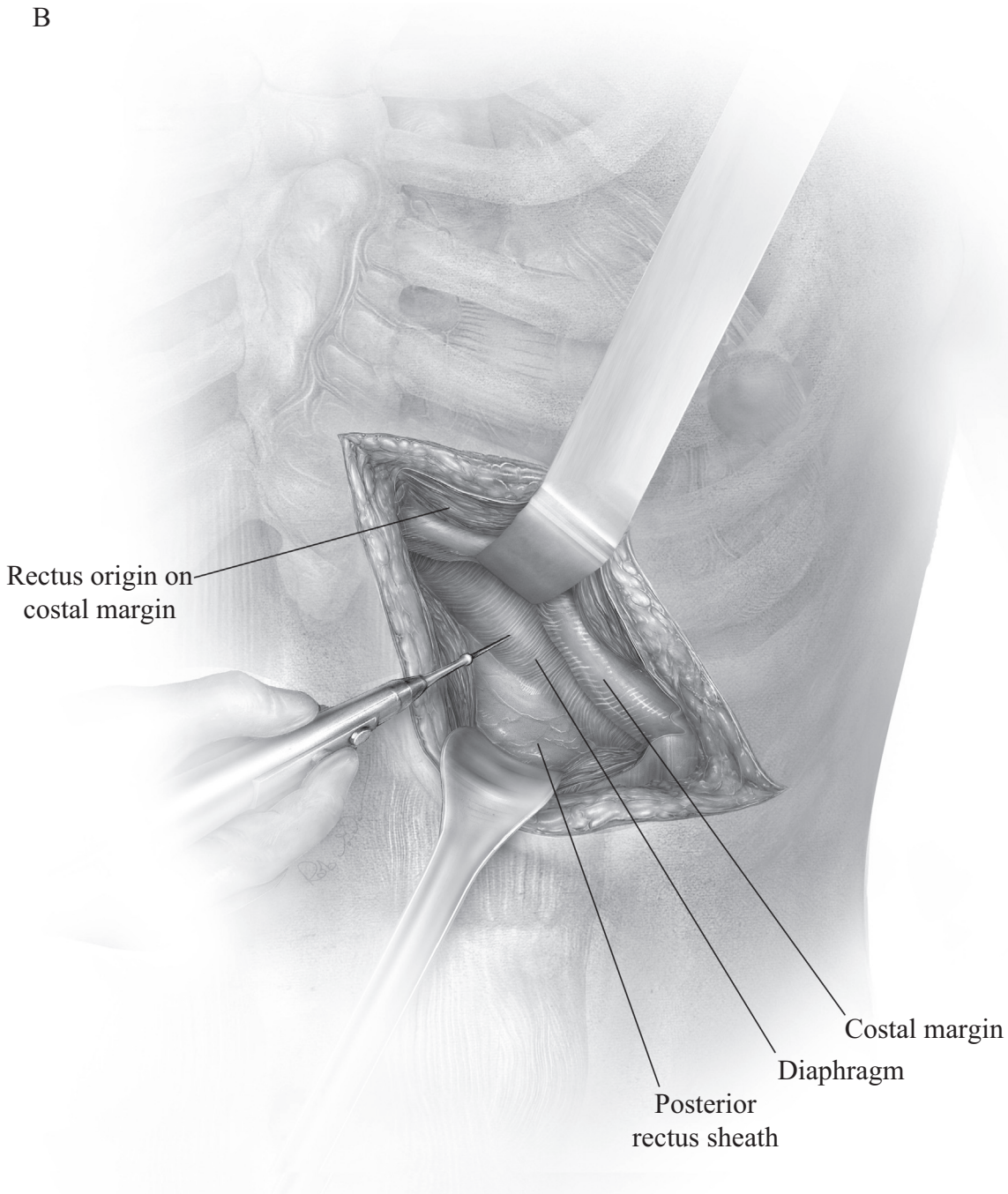

Figure 2 (*Continued*) (B) This is developed inferiorly, laterally, and medially. Medially, the xiphoid is disconnected posteriorly from all muscular and fascial attachments, to allow later passage of the outflow conduit deep to the xiphoid. The preperitoneal plane is entered deep to the xiphoid and is developed slightly inferiorly and to the right of the midline using a finger. Superiorly, the pocket is developed by dividing the attachments of the rectus to the costal margin. The diaphragm is then encountered and is divided with cautery to gain entry to the left pleural cavity. The pleuropericardial fat pad is incised to expose the pericardium. Subsequent exposure of the pericardium and the heart is achieved using a self-retaining retractor to elevate the costal margin (Thompson liver retractor [Thompson Surgical Instruments Inc, Traverse City, MI]).

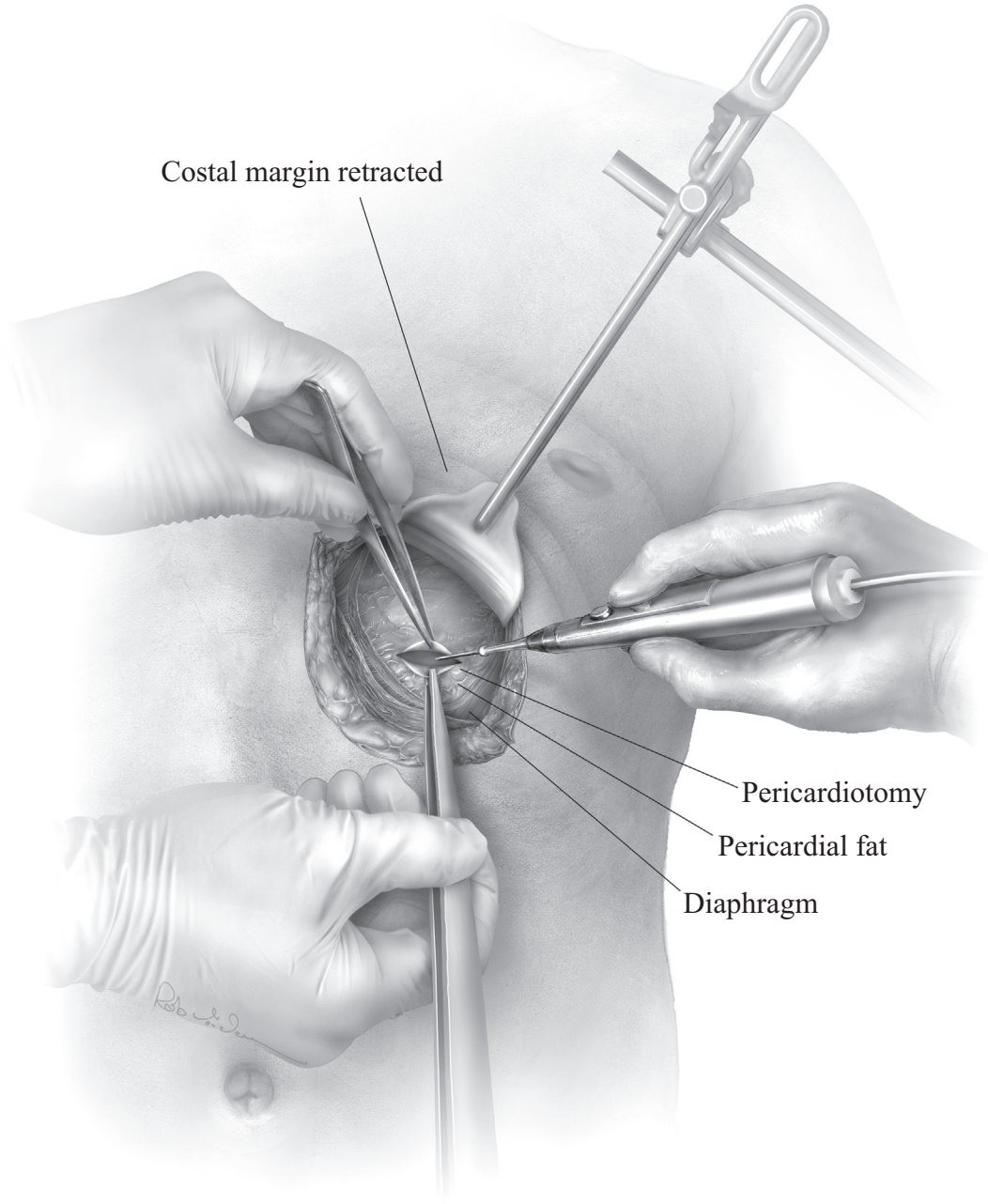

Figure 3 A transverse incision is made at the base of the pericardium. This incision is extended laterally to the apex. The incision should be stopped just short of the apex, as more lateral extension can injure the left phrenic nerve. Medially, the incision is extended to the right of the xiphoid process. The pericardial cavity is inspected for adhesions. If there are severe pericardial adhesions, then subsequent steps to access the ascending aorta should be achieved through an upper hemisternotomy (this is rarely required). If there are mild or moderate pericardial adhesions, then a minithoracotomy incision is still made as adhesions can easily be divided once on cardiopulmonary bypass.

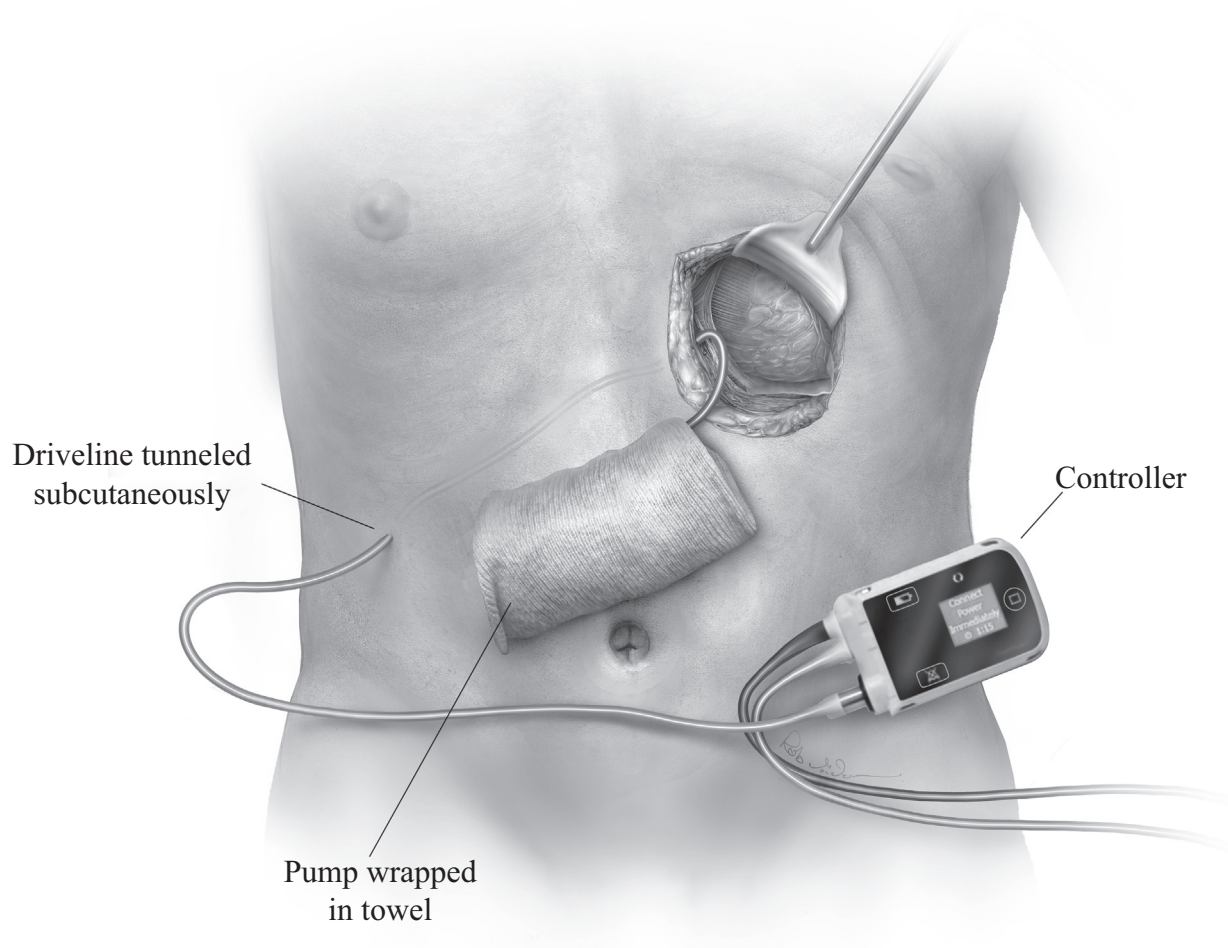

Figure 4 The left ventricular assist device has been prepared according to the manufacturer's recommendations and is introduced through its pocket with the driveline exteriorized to the right upper quadrant.

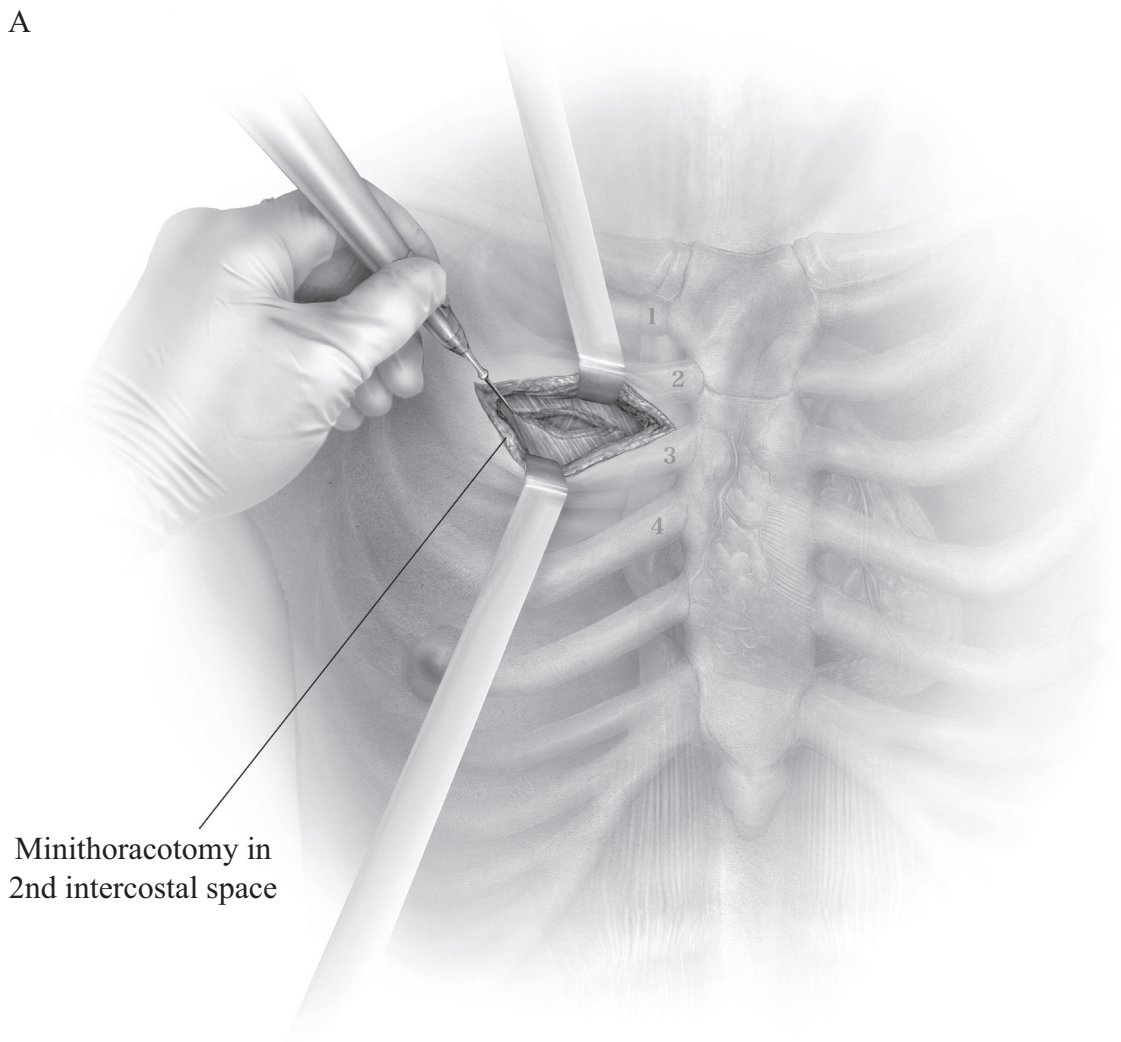

Figure 5 Surgical exposure: right minithoracotomy. This incision is not commenced until severe adhesions in the pericardial cavity have been excluded through the subcostal incision. A right minithoracotomy is performed via a transverse incision, typically 4-6 cm long, over the second intercostal space, approximately 1 cm lateral to the sternum. The pleural cavity is intentionally entered. The internal mammary vessels are ligated, with doubly applied hemoclips, and divided. A soft tissue retractor (Edwards Lifesciences, Irvine, CA) and a small rib-spreading retractor are used to facilitate exposure. Extrapericardial fat is incised to expose the pericardium over the aorta and the right atrium. The pericardium is incised longitudinally.

B

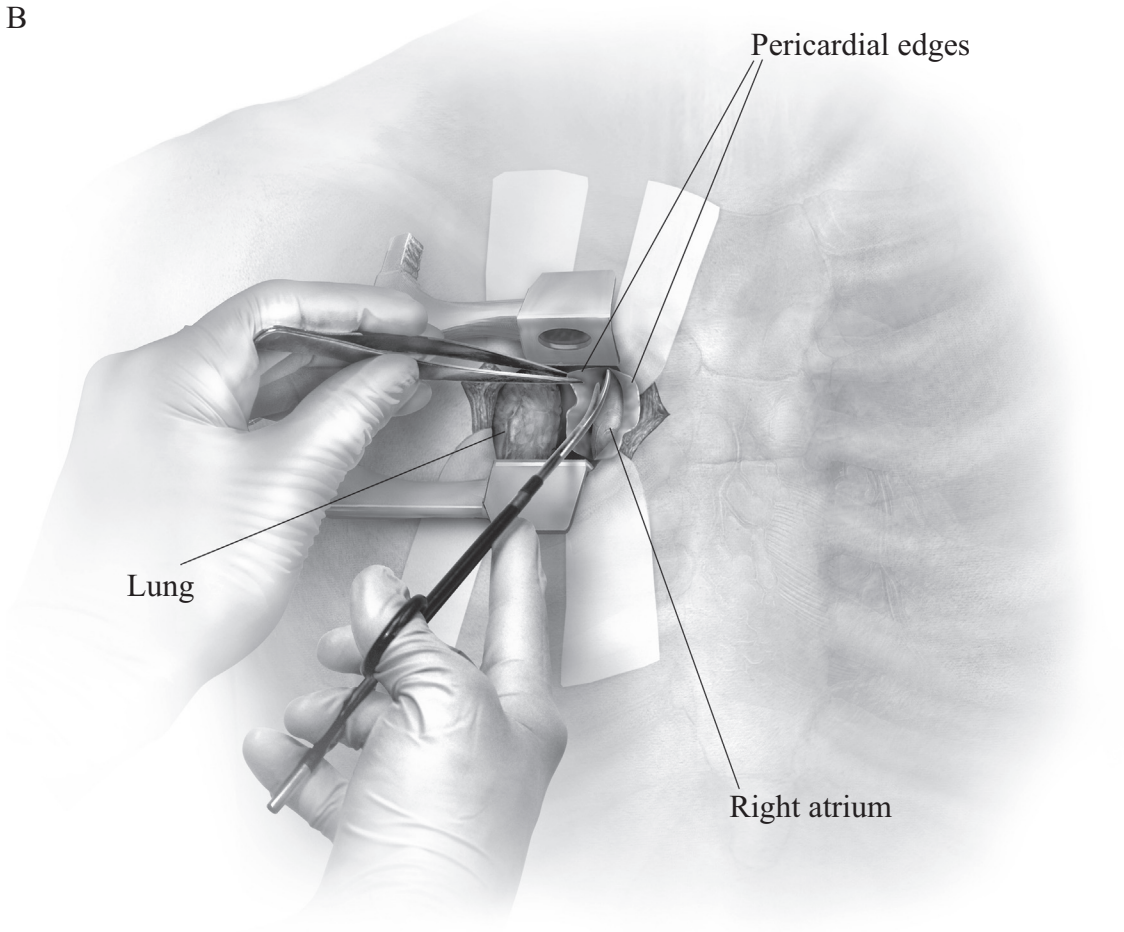

Figure 5 (*Continued*)

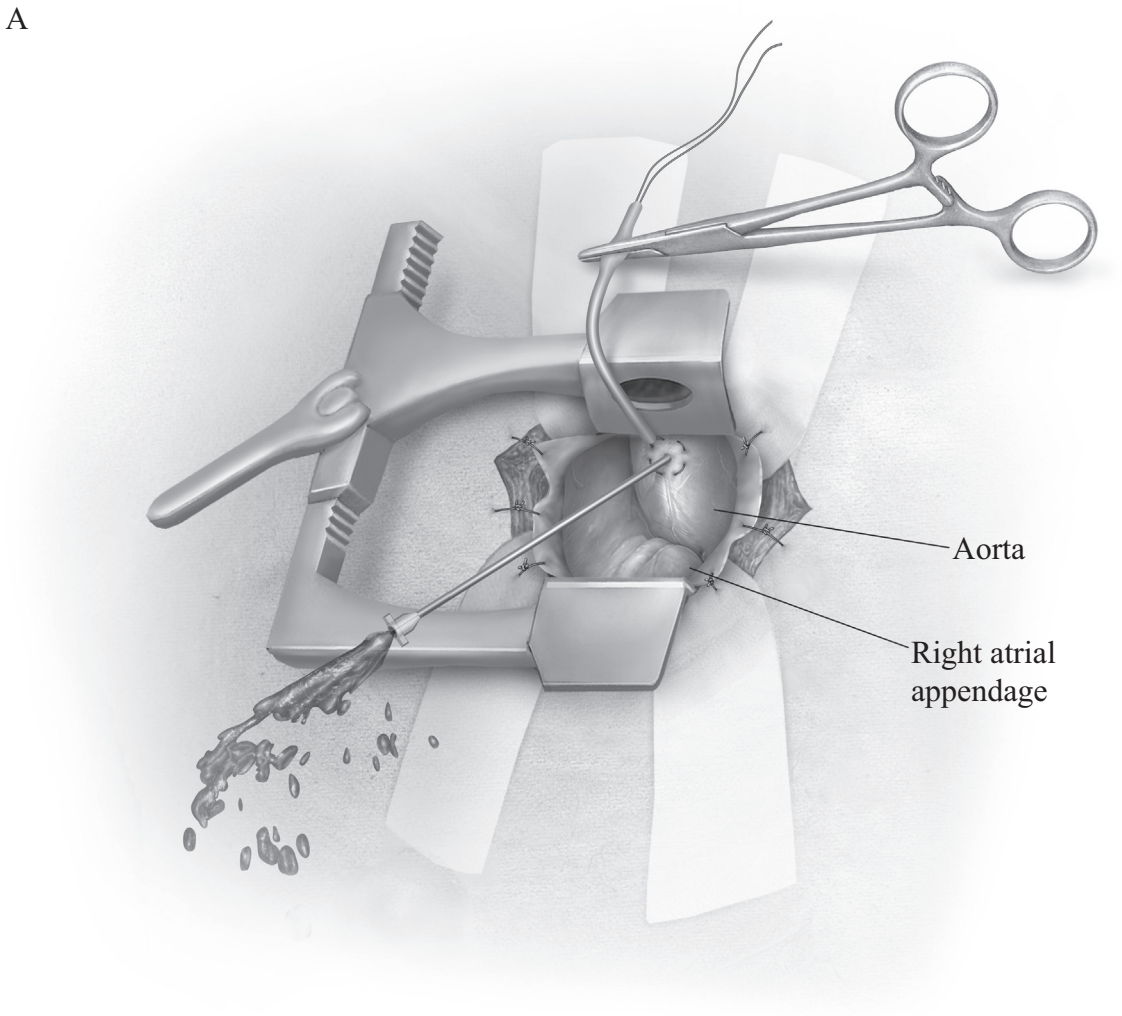

Figure 6 The pericardial edges are hitched to the wound edge to allow exposure of the aorta. The patient is heparinized. The aorta is gently retracted with forceps, and an area for cannulation is identified in the distal aorta. Enough space must be left on the proximal aorta for later placement of a side clamp (Fig. 10). Then, 2 concentric polypropylene purse-string sutures are placed. As access is limited, placement of these sutures is facilitated using long shafted instruments. The ascending aorta is cannulated using the Seldinger technique—this secure and controlled method allows safe cannulation of the aorta from a distance without direct digital control. A wire is advanced through a needle into the descending aorta under transesophageal echocardiography guidance. A suitably sized femoral artery cannula is advanced over this wire. Dilators are not used, but if necessary, the aorta may be incised with a no. 11 blade to facilitate passage of the cannula. The cannula is secured. The right atrial appendage is cannulated with a single-stage cannula (a dual-stage cannula may also be used, but extreme care should be taken to advance this in the direction of the inferior vena cava to avoid perforation of the right atrium, right ventricle, or coronary sinus). If there is difficulty accessing the right atrial appendage, 2 angled venous cannulae are placed in the superior vena cava, or alternatively the femoral vein may be cannulated percutaneously. Cardiopulmonary bypass is instituted, and adequate drainage of the right ventricle is confirmed by echocardiography. The left pleural cavity is flooded with carbon dioxide.

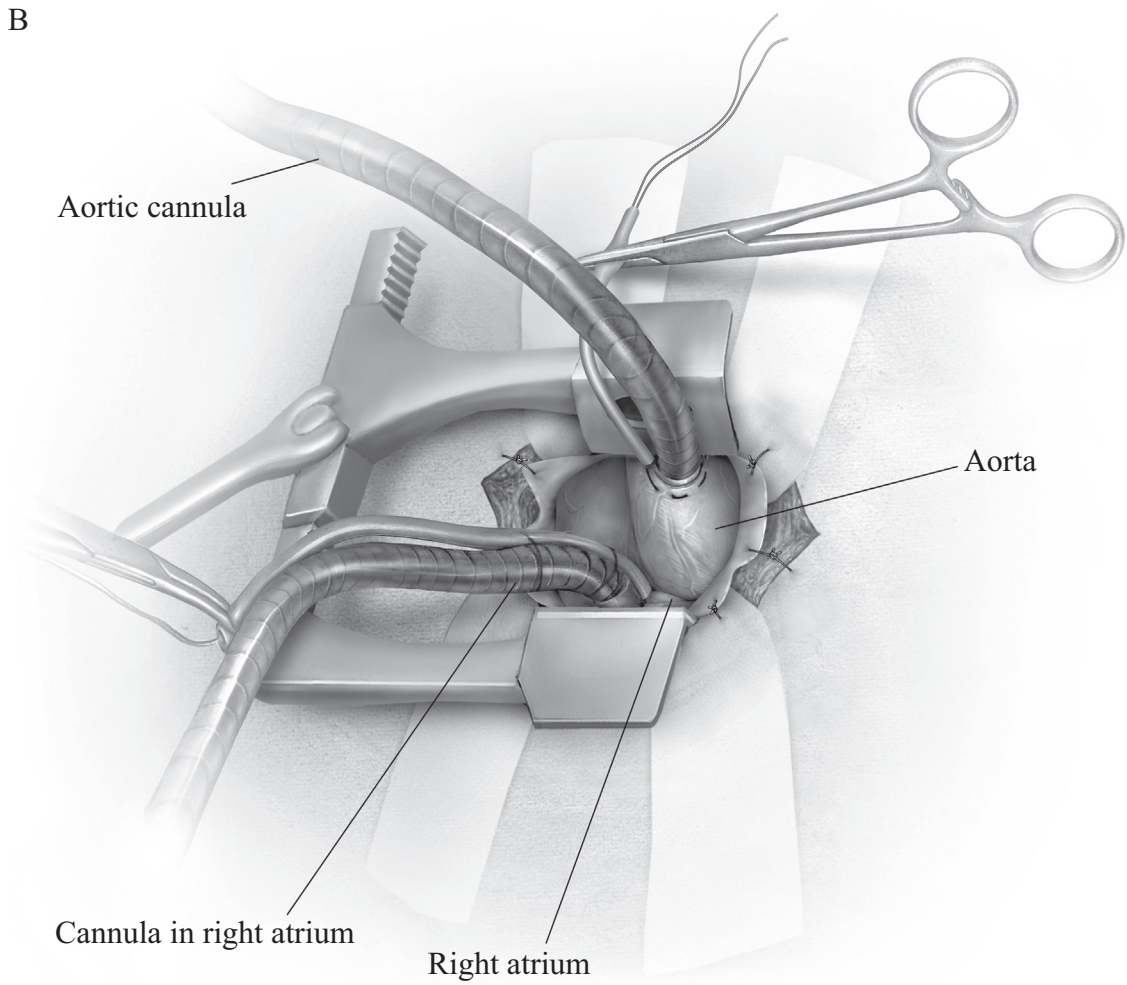

Figure 6 (*Continued*)

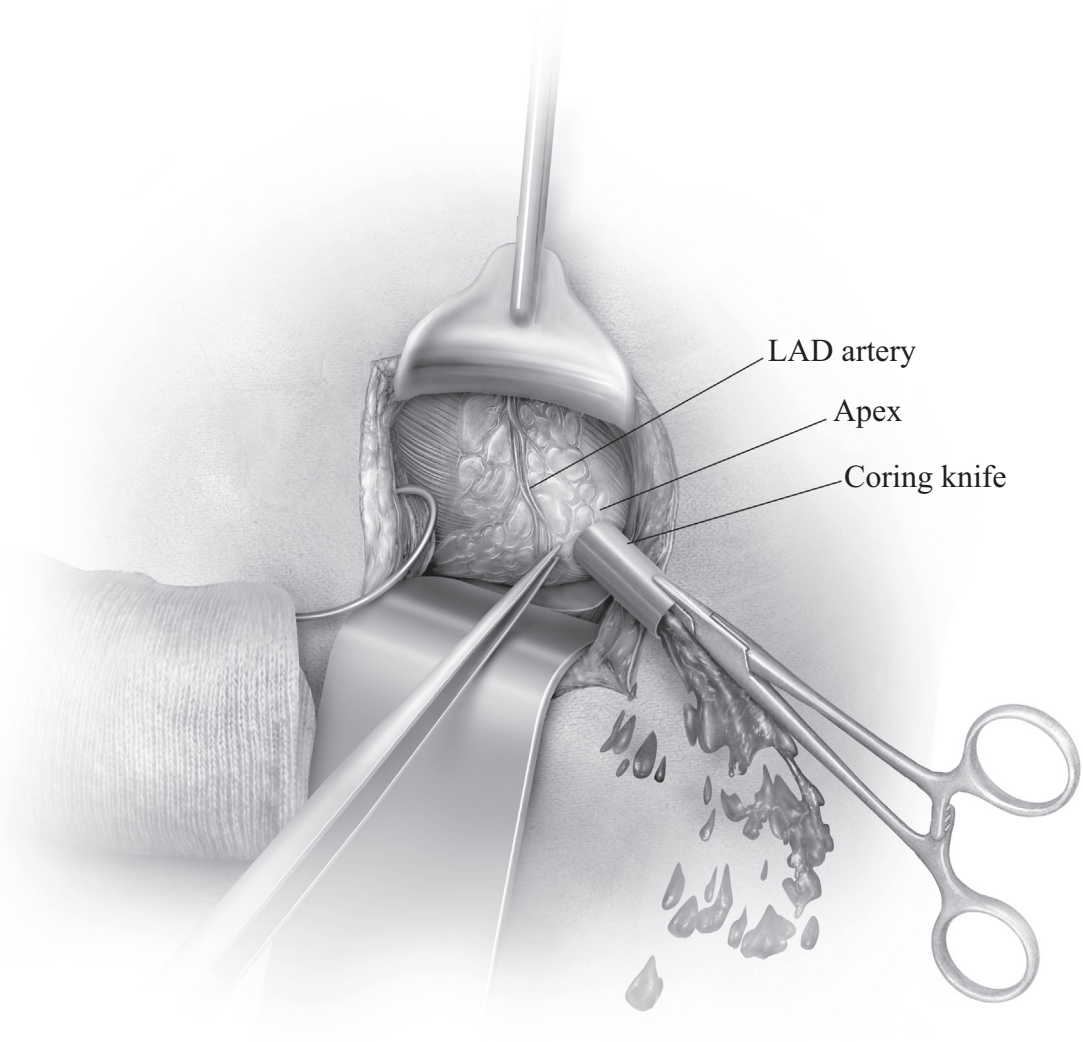

Figure 7 Coring. The patient is placed in a steep head-down position. The pericardial edges may be hitched to the edge of the subcostal incision. A broad malleable blade of the Thompson retractor (Thompson Surgical Instruments Inc, Traverse City, MI) is used to retract the basal pericardium caudally. The apex of the heart is now easily seen within the subcostal incision and is grasped with forceps and cored with the coring knife. The ventricular cavity is inspected for thrombus and trabeculations, which are excised as necessary.

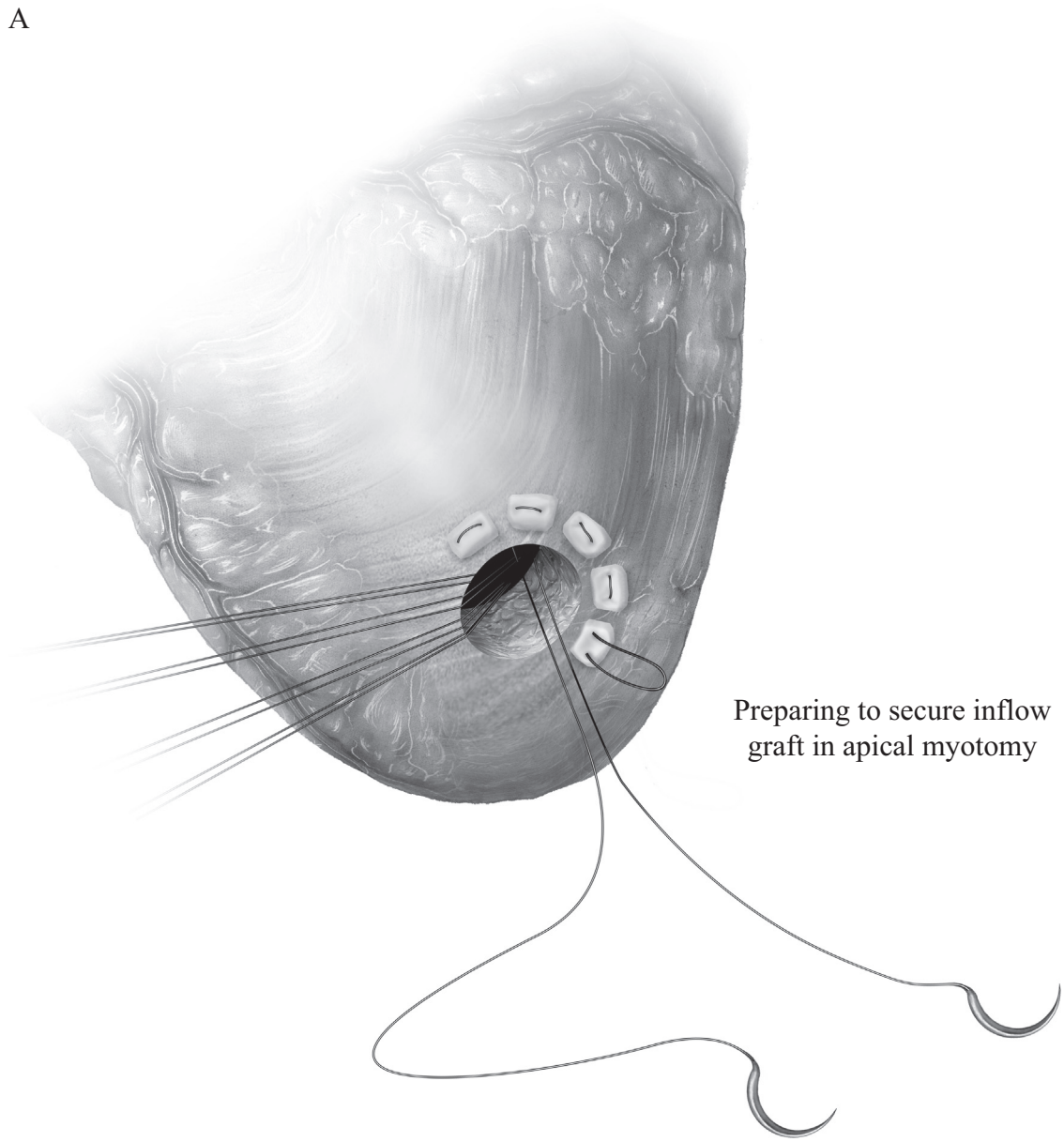

Figure 8 Placement of the inflow cannula. Eight 2-0 braided polyester sutures with broad pledgets are placed through the cardiac apex and through the sewing ring of the HeartMate device. Shafted instruments may facilitate this process. The sewing ring is tied down securely. Where the incision is small and the heart distant, a knot-tying device (Cor-Knot [LSI Solutions, Victor, NY]) may facilitate this process. Biological sealants may be applied if desired. The inflow cannula of the LVAD is introduced into the sewing cuff and advanced into ventricle and is then secured with ligatures. A de-airing vent is connected to the outflow limb of the LVAD pump.

B

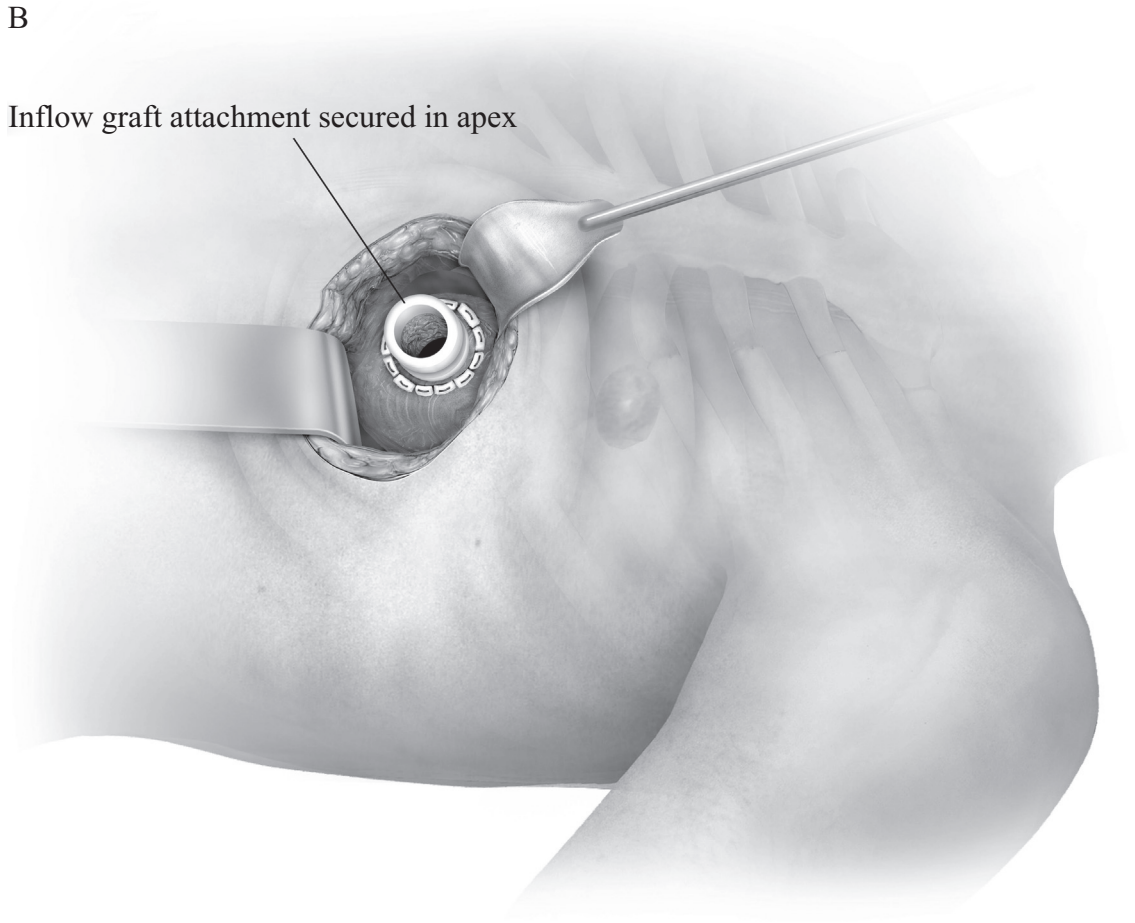

Figure 8 (*Continued*)

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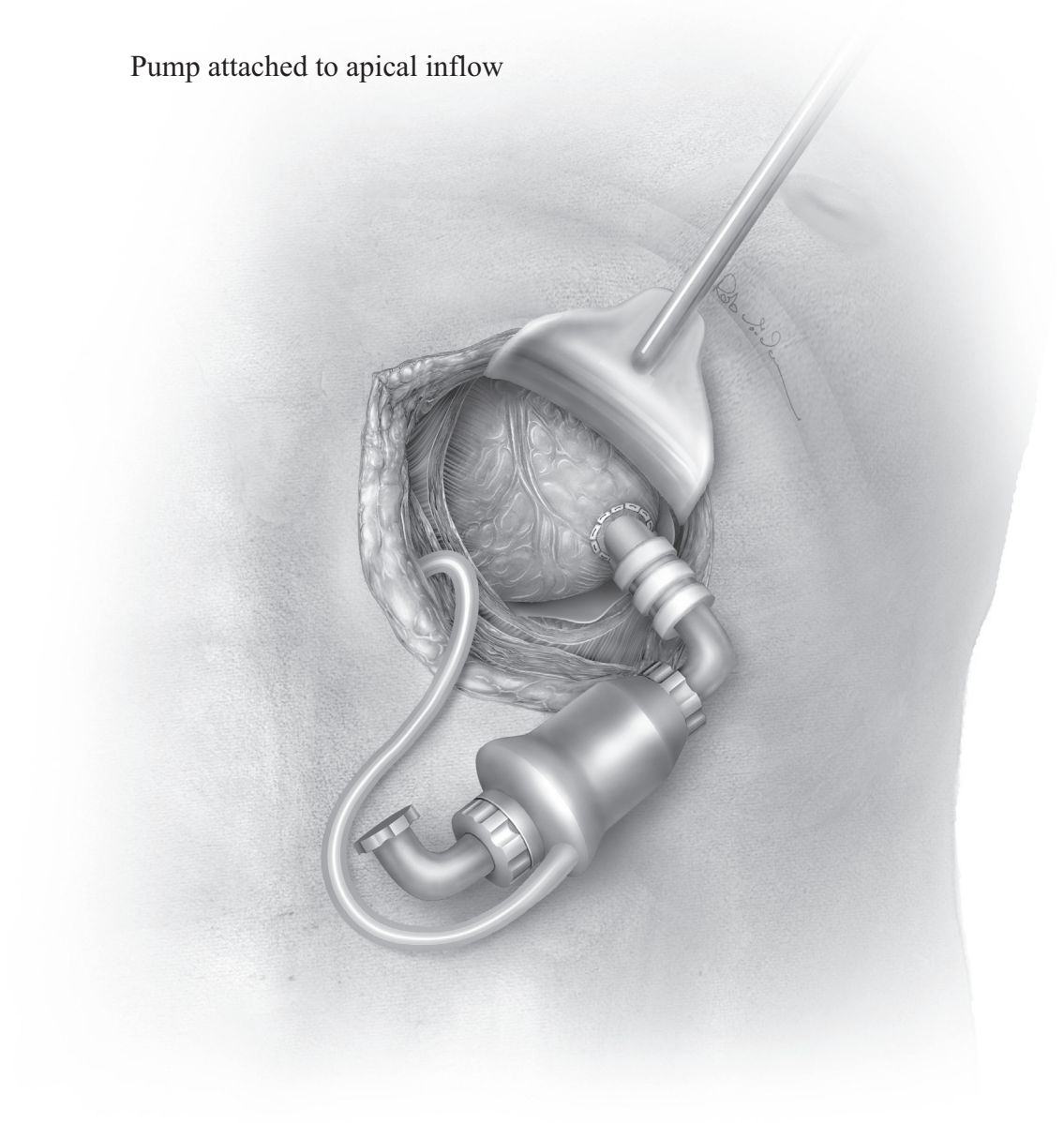

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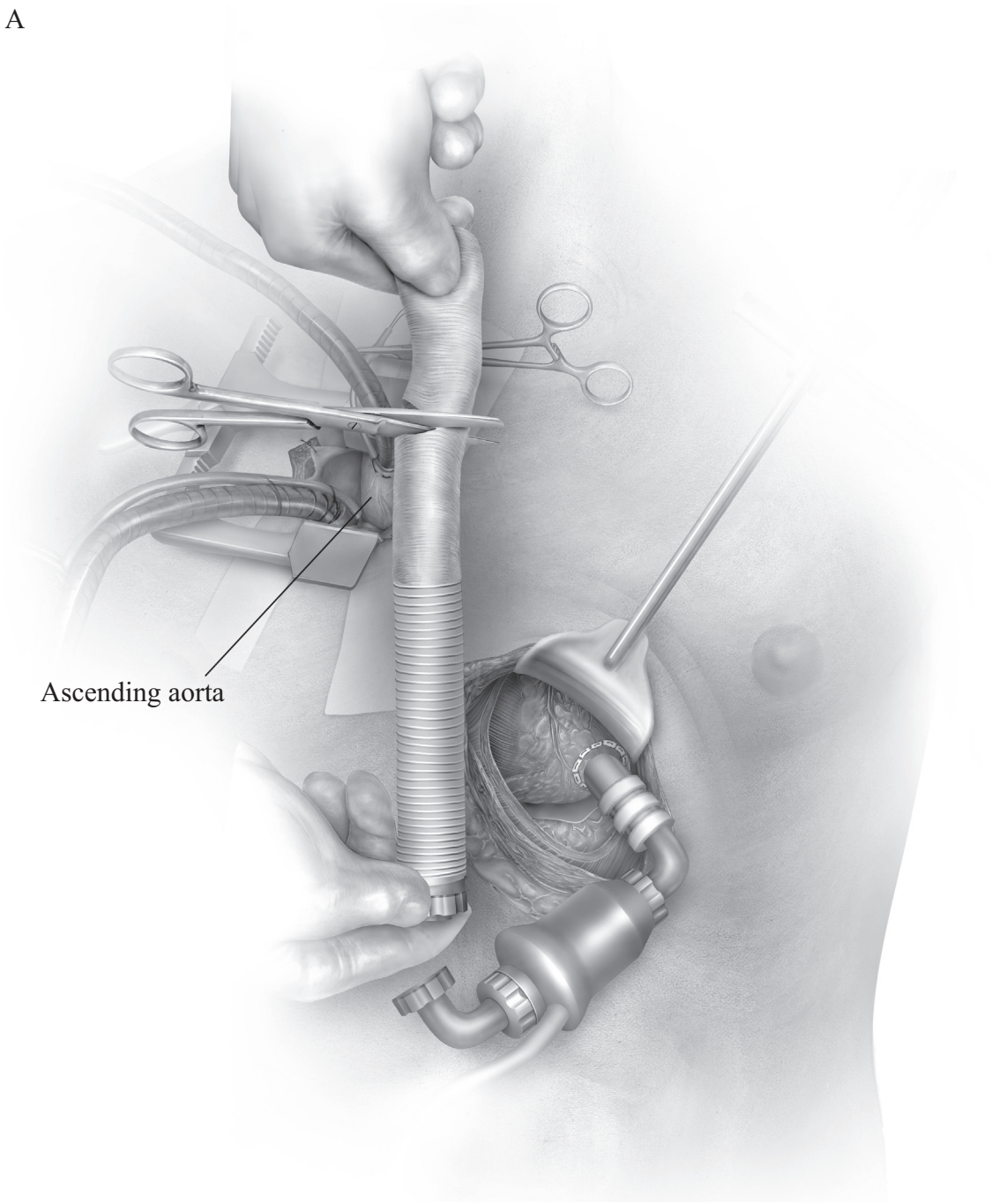
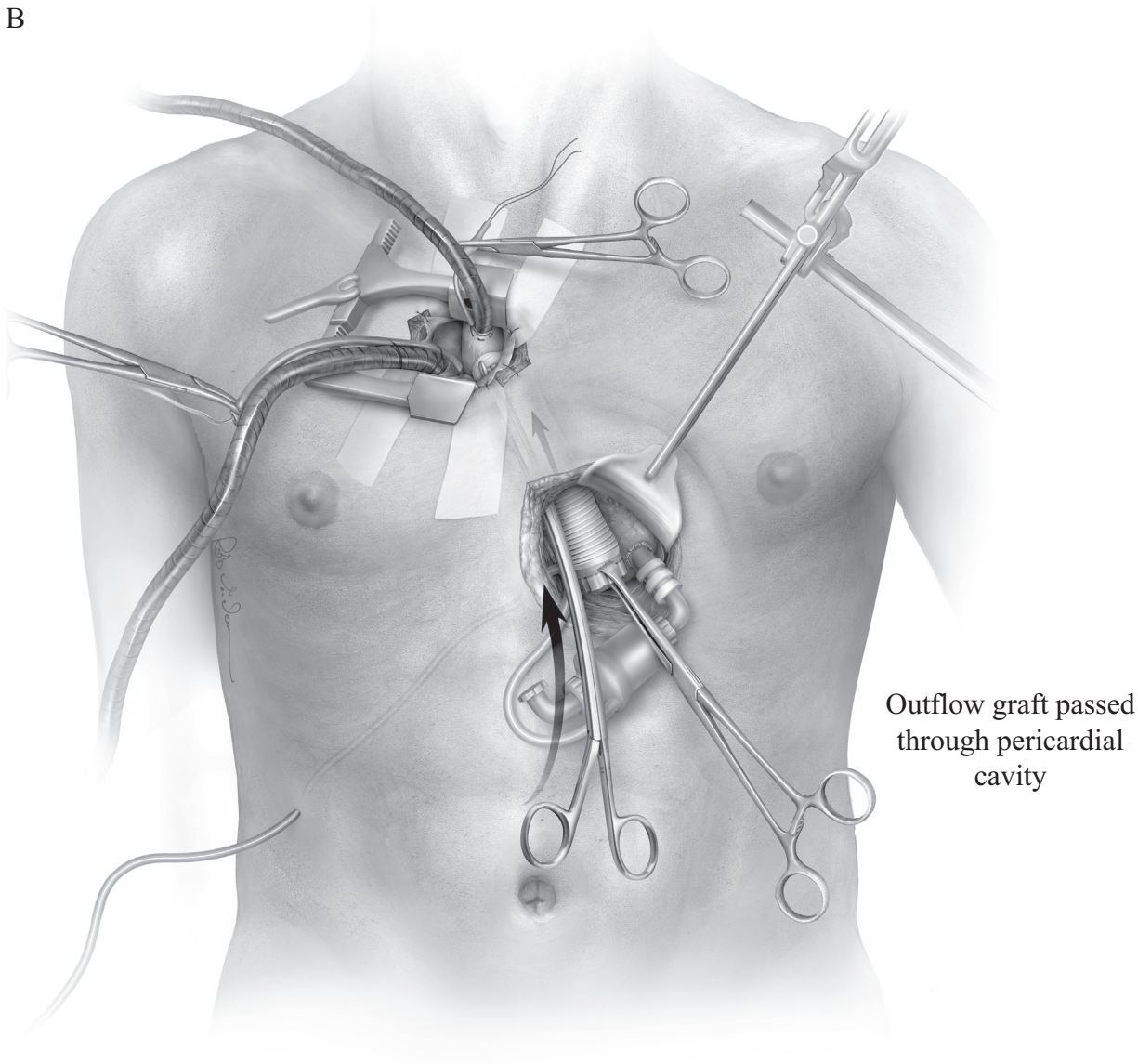


Figure 9 The outflow graft is measured by holding it stretched and measuring the distance from just below the xiphoid to the minithoracotomy incision. Approximately an inch is added to the measured distance to allow easier connection to the pump later (Fig. 11). The divided outflow graft is placed within the bend relief. The end of the outflow graft is grasped with a chest tube puller and passed from the subcostal incision, through the pericardial cavity, over the right ventricle and then grasped from the minithoracotomy incision. A polypropylene stay suture is passed though the graft and used to hold it in place. Before tunneling the outflow, an Allis clamp is used on the metal screw-in end to allow subsequent easy retrieval for later connection to the pump (Fig. 11).

B



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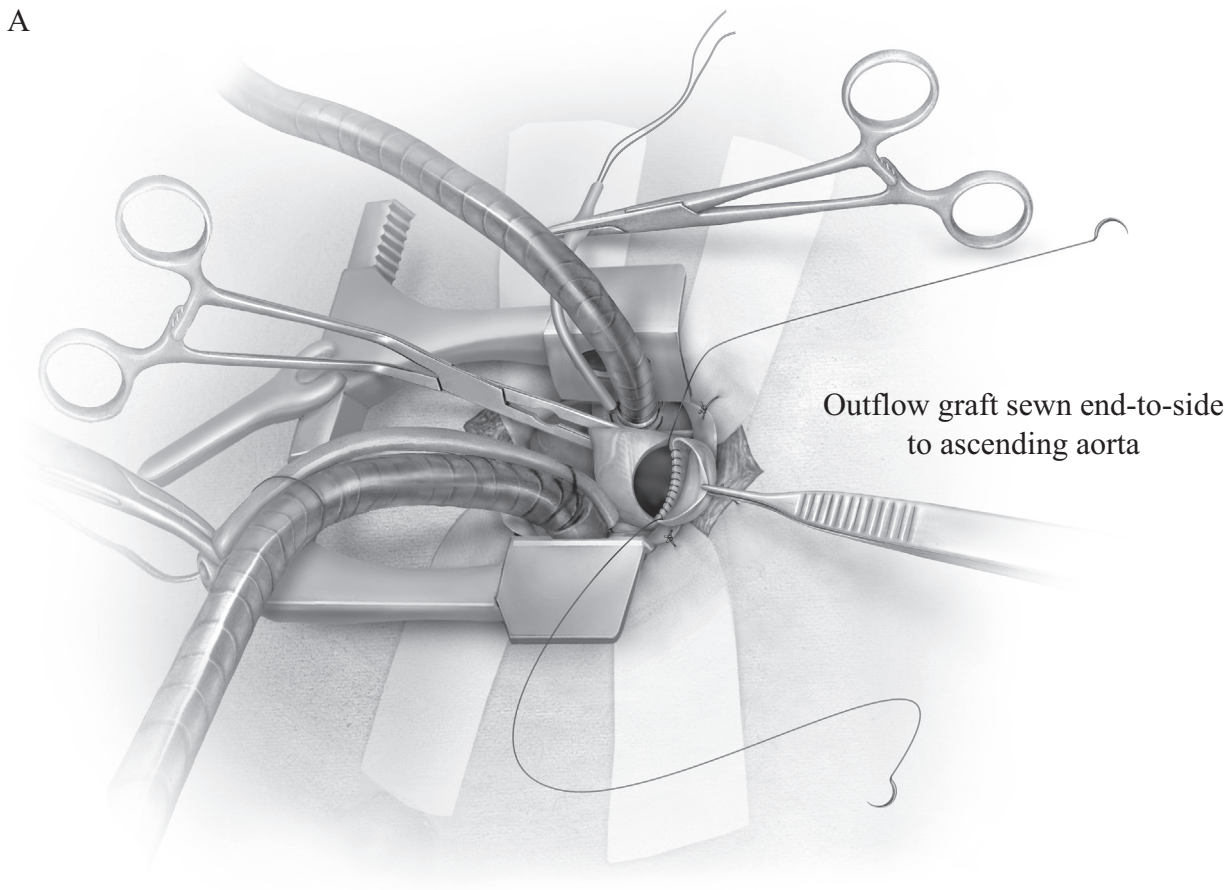
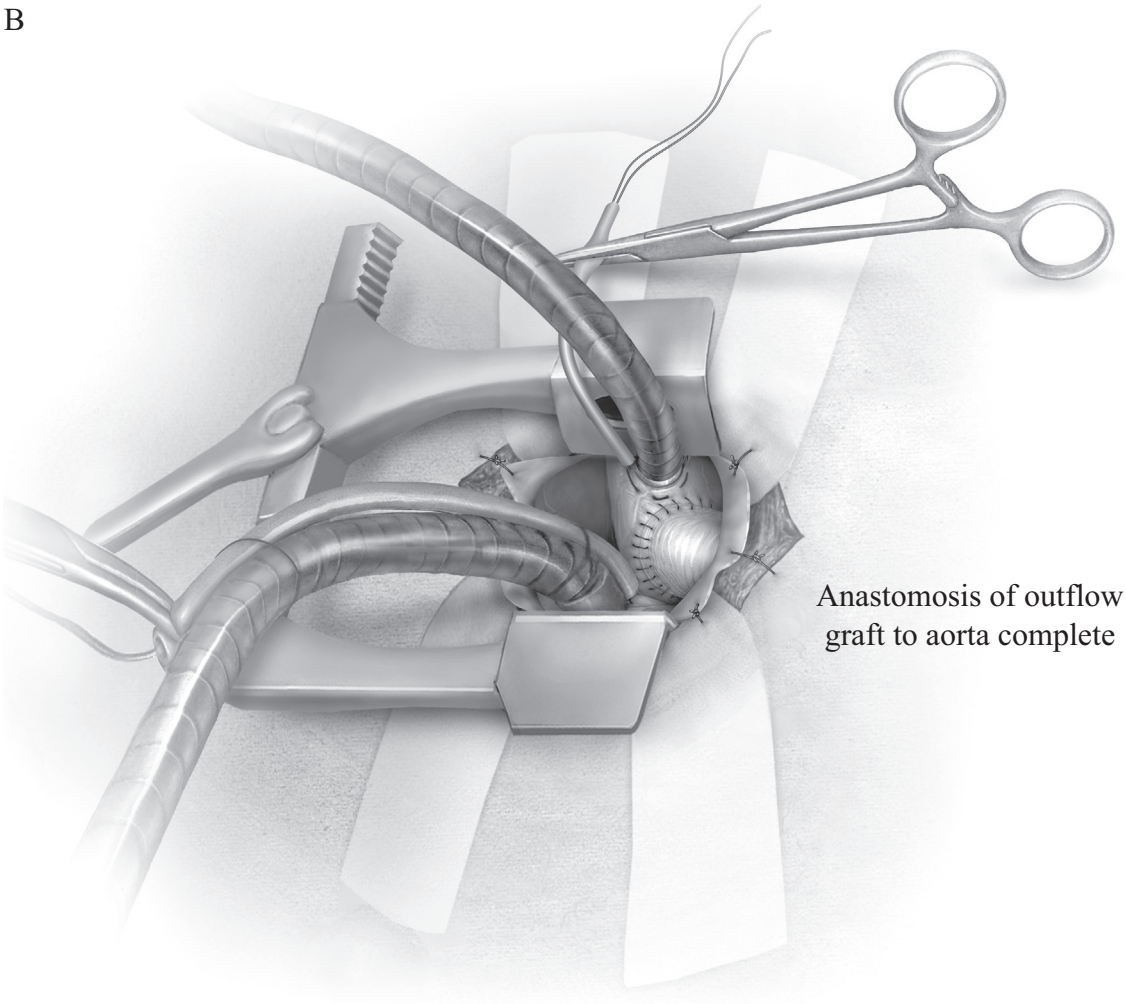


Figure 10 Suturing of the outflow graft. A Lambert-Kay vascular clamp is then placed on the proximal ascending aorta. A longitudinal aortotomy is performed. The aortotomy may be enlarged with sequential use of an aortic punch if necessary. The outflow graft is then anastomosed to the ascending aorta with a continuous 3-0 polypropylene suture. The clamp is removed, and a clamp is placed on the proximal aspect of the outflow graft through the subcostal incision.

B



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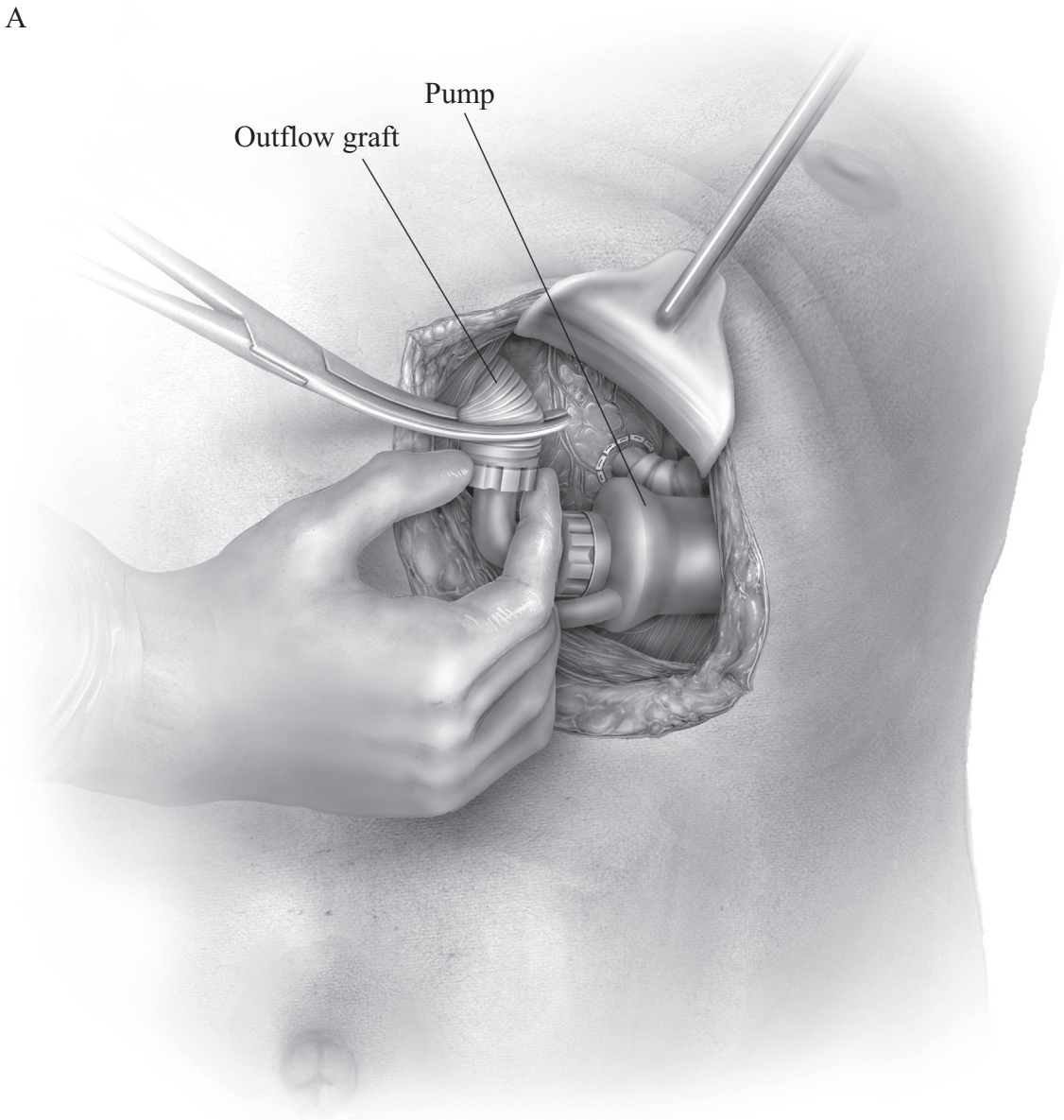

Figure 11 (A) Connection, de-airing, and starting of the LVAD. The outflow graft of the LVAD is connected to the pump. This may be difficult because the limited access may prevent getting both the hands into the wound—in that case, this is facilitated by using tube clamps to hold the pump and turn the screw. De-airing is undertaken through a needle in the proximal aspect of the outflow graft and a needle in the ascending aorta.

B

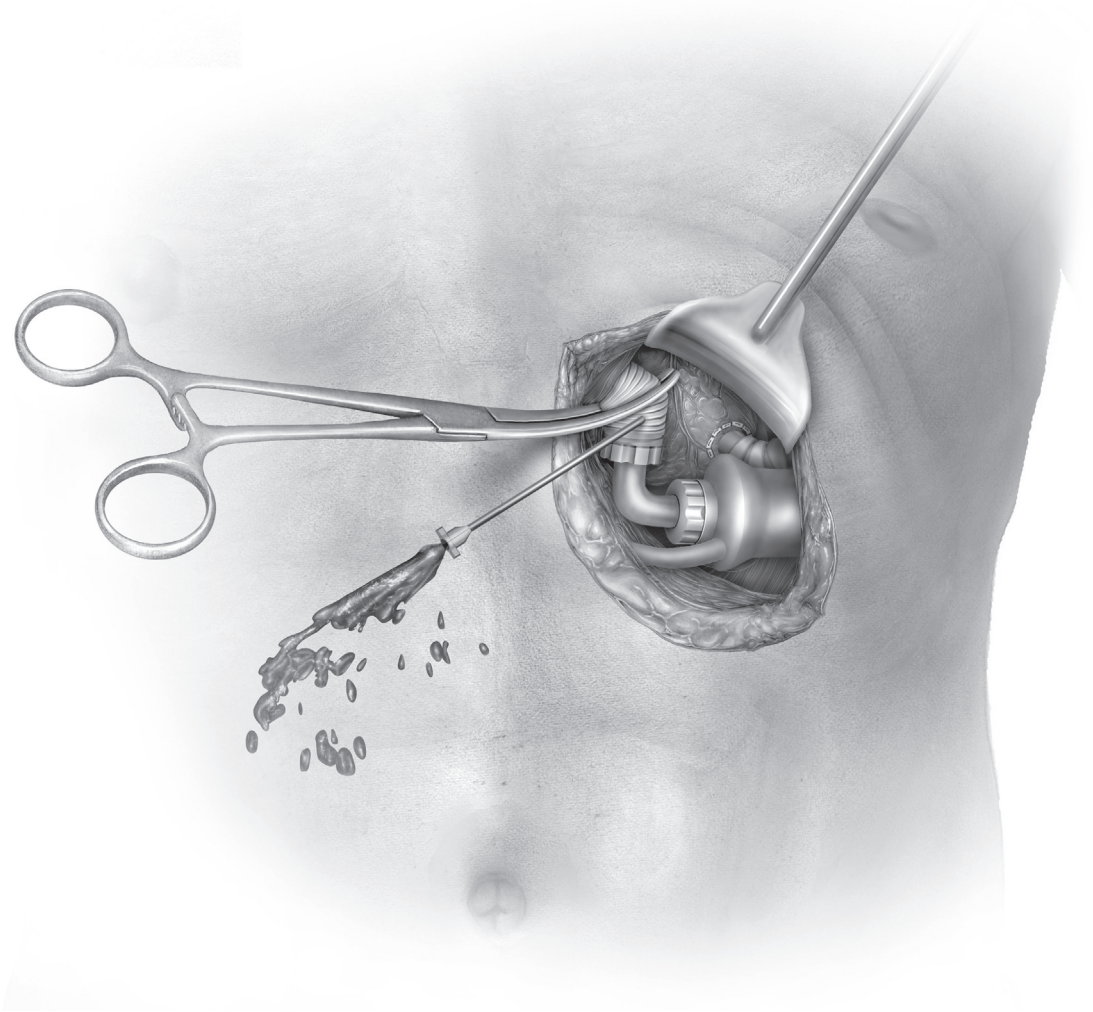

Figure 11 (*Continued*) (B) The pump is then positioned within its pocket (during de-airing, the outflow half of the pump usually juts out of the wound) Pump support is then initiated.

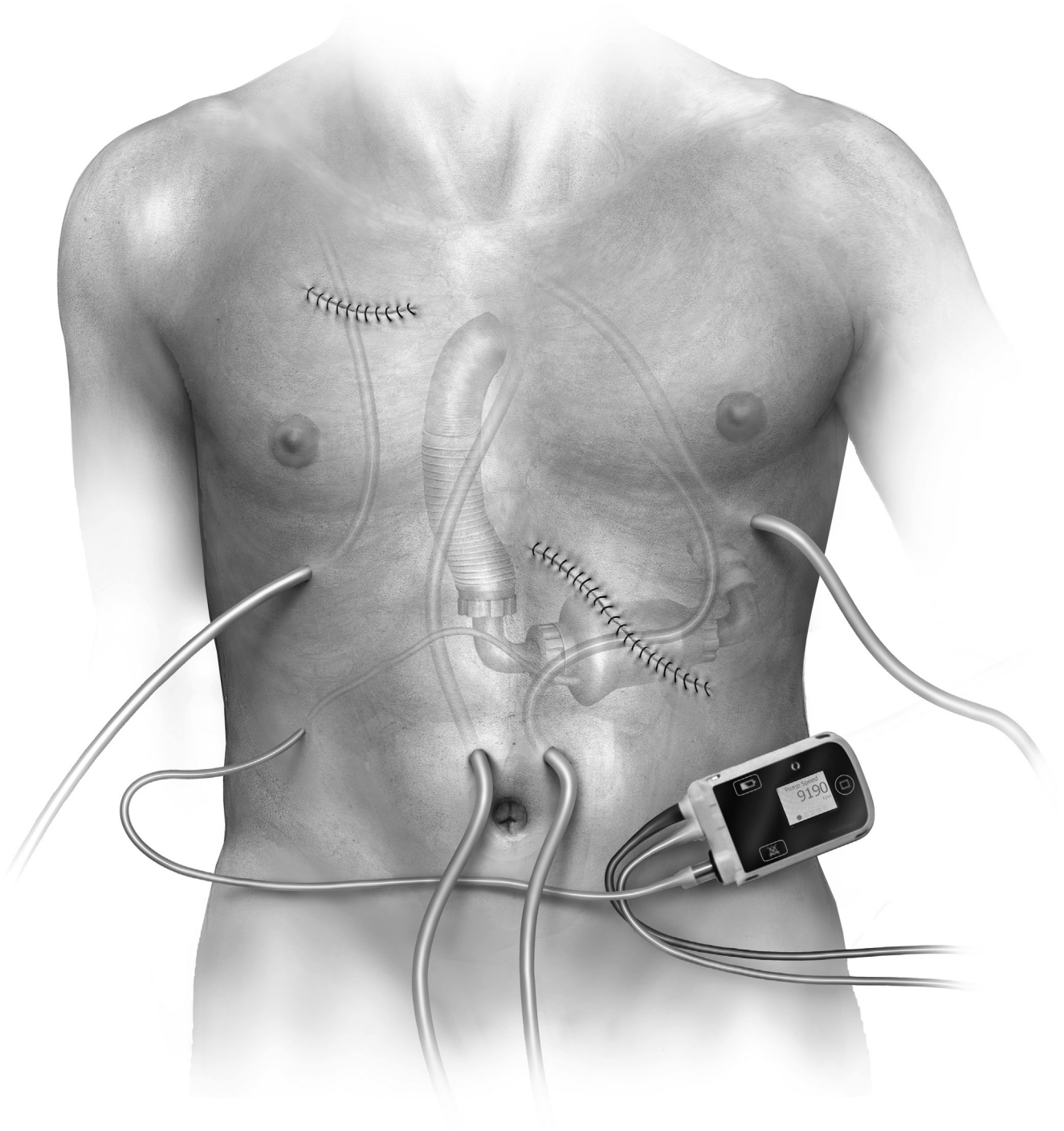

Figure 12 Closure. Heparin is reversed and cannulae are removed. Hemostasis is usually brief, as there are limited sources for surgical bleeding. Chest tubes are placed. The pump is then placed in its final position—this is facilitated by tugging on the driveline to displace the pump medially, such that the outflow limb now lies beneath the xiphoid. Using 2 fingers, one placed in either incision, the outflow graft is positioned such that it lies lateral to the right atrium as opposed to anterior to the ventricle (where it would have been located till this point), and the outflow graft enters the aorta from a lateral as opposed to an anterior direction. The pump is secured to the abdominal wall with a polydioxanone suture to prevent pump migration. We then reapproximate the pericardium, both over the base of the heart and over the aorta. The surgical incisions are closed with absorbable sutures.

Comment

We have found this technique to be reproducible and not found a need for conversion to full sternotomy in more than 50 cases. The potential advantages include less bleeding and less blood transfusion, quicker wean off the ventilator, absence of major wound complications, possibly less right ventricular dysfunction, and an easier transplant operation. Disadvantages include greater technical difficulty, longer cardiopulmonary bypass times, and limited scope to deal with complications or problems. Notably, placement of a right ventricular assist device is problematic—we have not required to do so in patients receiving LVAD via this approach, but this could possibly be done with inflow from the femoral vein and outflow into the right pulmonary artery via the minithoracotomy incision or with a cannula through the right ventricle free margin via the subcostal incision, guided through the pulmonary valve. Postoperative care and subsequent management are the same as those for an LVAD implanted via sternotomy.

Reference

1. Anyanwu AC, Itagaki S, Pinney S, Adams DH: Initial experience with routine less invasive implantation of HeartMate II left ventricular assist device without median sternotomy. Eur J Cardiothorac Surg 46(6):985–990, 2014. http://dx.doi.org/10.1093/ejcts/ezu044.